

Architectural heritage of the north eastern Portugal: History, construction and valorisation

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ABSTRACT: This article is based on a study carried out in different small houses located along the margins of the Tua River, in the county of Alijó and Carrazeda de Ansiães, in order to perform a characterization of constructive techniques and materials. It is considered as a constant goal throughout this study the appreciation of natural stone, in this case granite and schist, as construction materials that were used in large scale in this region in the past and continue to be applied in the present, encouraging and valuing its use as a construction material.

1 INTRODUCTION

The vernacular heritage is a symbol of cultural and historical values, assuming a common heritage is timeless, which must be preserved for future usufruct. However, the sudden rupture with traditional principles, with the fast adoption of modern techniques, led to a loss of identity of people and places. The transition phase that would allow the combined use of traditional and modern materials practically did not exist. This is one of the reasons why older materials were seen as elements with little power to answer to new concepts of architecture and engineering requirements.

This abandonment, in spite of gradual, is due in large extent to the lack of studies and scientific analyses on the potential of traditional materials. Part of this knowledge was only transferred verbally across generations, but most of these people are disappearing, without any registration of the information for future implementation. The reintroduction of traditional materials such as stone is, nowadays, essential once the remaining resources tend to run out and the pollution resulting of its manufacture and rubble produced is becoming unsustainable.

With this respect it is considered important to collect and to document the constructive past of the vernacular architecture of a country. The construction of Foz Tua dam, located on the edge of the Douro region, declared a World Heritage of Humanity, will cause the submersion and the dismantling of traditional constructions (stations, way stations, mills, millers' houses, shelters, water-mills). This situation led to a few studies that collect the architectural and ethnographic evidences of the region, culminating in the preparation of this doc-

ument. From a geological and lithological point of view, Tua region is characterized by granitic rocks and metasedimentary formations (mainly schist). In fact, the stone quarries are extremely abundant in the region, which is a raw material available, accessible and widely used in vernacular houses of the region. The use of natural resources near the construction site, such as, stone, earth, wood, cork, constituted a common practice in the past, which characterize the constructive heritage of the place. The regions of Estremadura, Ribatejo, Beira Litoral, Alentejo and Algarve unlike the region of Trás-os-Montes and Alto Douro are characterized by a high number of wooden houses (in the littoral), rammed earth and adobe, given the scarcity of stone available in these locations.

2 RESEARCH METHODOLOGY

The methodology selected for this research work is based on an analysis of stone masonry houses abandoned along the Tua railway, already previously identified by Paulino (2011). A qualitative approach was adopted by obtaining informal interviews with locals, site visits and documentation of houses, through photographic record and simple techniques of visual inspection (baroscopic camera), and indirectly by means of information gathered in the literature (bibliography, documentation on files). Based on this, the research presented here is encompassed in three phases:

1. Selection of the constructions around the Tua River to study. This selection was performed according to three parameters, namely: layout area, conservation status and relevance of the construction for the region.

2. Compilation of the information: preparation of technical files as complete as possible relating to the constructions under analysis, namely: the photographic record, geographical location, altitude, accessibility, protection status, condition, patrimonial value, owner identification, architectonic description (construction technique, materials, cross-section of the walls, stone type, functionality), survey geometry (layout and elevations).
3. Constructive characterization. After the collection and compilation of information relating to vernacular architecture of the Alto Douro region, it will be prepared a document that stresses the possibility to use natural stone, granite and schist, as a constructive material against the concrete and steel, which are currently the main structural materials used in an almost exclusive form. On the other hand, it aims to demonstrate that the adoption of natural stone as a constructive material for traditional housing of the Alto Douro region is an eco-efficient option.

2.1 Selection of the constructions

The constructions selected for further constructive and patrimonial characterization were divided according to the following typology: watermill and/or weir, haystack, housing and mill. It should be mentioned that the materials characterization and typology identification of the masonry walls will be useful for the construction of laboratory models for further experimental characterization, aiming at obtaining the key mechanical properties. The selection of the constructions was conducted in accordance with the following parameters:

Layout area—it was considered a minimum area of 15 m² for integrating construction in this study. Only the structures with area equal or greater than this value were selected.

Conservation status—the constructions in a state of ruin were excluded. The conservation status was classified as good (G), slightly degraded (SD) and markedly degraded (MD).

Relevance of the construction for the region—according to the characteristics of the Tua valley and lifestyle of its population. It was considered with constructive relevance the watermill/weir, the mills, the dwelling houses and haystacks. The furnaces, shelters and wells were excluded due to their lower impact in the dynamic of this region. In total, 15 constructions were studied, see Table. 1.

All the constructions selected had to accomplish the three parameters referred, and the simple violation of one of them implied their automatic elimination. Some structures were identified with great constructive relevance but with extreme

level of degradation and other structures with reduced area and insignificant importance, but well maintained. In Figure 1, the mapping of the constructions that were covered by this study is presented.

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2.2 Compilation of the information: Technical sheet

After local visits and using the ESREP (Environmental Status Report of the Execution Project) of hydroelectric exploitation of Foz Tua, data sheets were prepared for each individual construction, which contained its specific location, constructive features, elevations and layouts. In Table 2 an illustrative data sheet of the constructions is shown.

2.3 Constructive characterization

After preparation the technical sheets for each construction and processing of all the information that characterizes the constructions of the study, it is achieved the final stage for the preparation of a more detailed document, which combines the respective data sheets and the more detailed information about the material and construction techniques.

For each typology (house, mill, haystack, watermill/weir) a constructive survey was carried out, which revealed the use of materials existing in the vicinity of the house, namely granite and/or schist. Next section describes the constructive elements identified.

2.3.1 Materials and masonry typologies

All the constructions identified have a specific functional purpose. The haystacks were used for storage (food for the animals, work tools). It is located in an isolated area in agricultural fields and pastures. The wills and watermills/weirs are located along the margins of the Tua River or water lines.

The watermills take advantage of the kinetic energy of moving water, whose original function was to grind the cereal grains, turning them into flour. The flow of water moves wooden casters that are attached to a grindstone (see Figure 2).

Table 1. Results of the selection of the constructions. Credits: The authors.

Typology	Number	Area (m ²)	Conservation state	Constructive relevance
house	4	≥ 15	SD	yes
house	6	≥ 15	G	yes
house	10	≥ 15	G	yes
house	12	≥ 15	SD	yes
house	14	≥ 15	G	yes
house	17	≥ 15	G	yes
house	24	≥ 15	SD	yes
haystacks	25	≥ 15	MD	yes
house/mill	29	≥ 15	MD	yes
house	38	≥ 15	MD	yes
mill	39	≥ 15	MD	yes
house	43	≥ 15	MD	yes
house	52	≥ 15	SD	yes
watermill /weir	54	≥ 15	SD	yes
house	55	≥ 15	MD	yes

G-good; SD – slightly degraded; MD – markedly degraded.

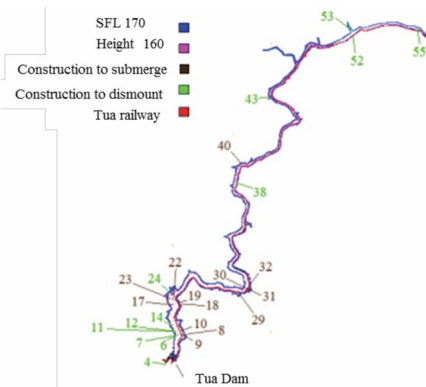


Figure 1. Mapping of the constructions target of the study. Credits: Paulino, 2011.

Housing and/or shelters' constructive typology was also identified. The shelters have a lower layout area. The dwelling houses have a layout area of about 50 m² and a ceiling of approximately 3 m. In Figure 3a, a house of vernacular architecture with single floor and rectangular layout is presented. The house presents roof with marseille tile and lean-to roof east oriented and two entrances north oriented. The house has regular granite masonry with cement mortar. In Figure 3b it is represented one house of vernacular architecture of a single floor with "L" plan view. This house has no roof anymore, which should be a lean-to roof. Two entrances exist oriented at north and one entrance



Figure 2. Construction 39 (Mill): (a) North elevation; (b) millstone. Credits: Authors.

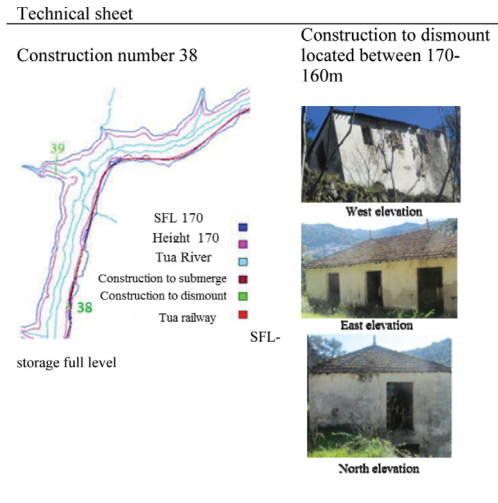
oriented at south. The masonry walls are built with schist, without mortar in between the stones and with varied irregular stones to reasonably carved stones.

2.3.2 Walls and coatings

The constructions under analysis are located in the region of Trás-os-Montes and Alto Douro. The frequent rural dwellings have walls of dry masonry carved or not, in granite and/or schist. The ordinary masonry is not current in this zone. In general, the houses have a single floor with rectangular layout with masonry walls of schist and/or granite, with distinct forms and irregular stones, well carved, without mortar to serve as a union.

The traditional houses identified revealed the presence of structural masonry walls with considerable thickness (0.50–0.81 m). The dimensions of the stone blocks applied are very variable in the same house. It is common to have in the same wall stones of medium/large dimension and little stones (cobblestone) to fill the empty space. The difficulty of accessing laying materials, such as mortar (lime or cement mortars), is a determinant factor for the adoption of dry stone masonry. In some constructions, double-leaf stone masonry was used for external walls, being both the leaves built with stones of irregular shape. The space created in-between is filled with smaller stone fragments. The connection between the leaves is assured by the placement of stiff large stones, which cross the entire thickness of the wall, allowing the adequate bracing between the panels. This technique enables better distribution of efforts between all structural elements, reducing the effects of differential settlements. The structures, generally, do not show outer coating and the apparent state of degradation of the stones results from the direct action of weathering agents, namely, climatic factors such as freeze and thaw cycles. Notice that it is common to observe some superficial disintegration of some stones, which should be associated to a prolonged exposition to weathering agents. Notice also that the region of Trás-os-Montes and Alto Douro is a region with important temperature amplitudes, being common the formation of ice during the winter.

Table 2. Technical data sheet of the selected constructions. Credits: The authors.



Toponym (origin)	Santa Luzia
Coordinates	x 62085.48
	y 179417.52
Datum	73
Altitude	165m
Location	District Bragança
	County Carrazeda de Ansiães
	Civil parish Pombal
	Place Santa Luzia
Typology	House
Conservation	AD
Protection state	Without protection
Owner	Not determined
Patrimonial value	Medium-high
Structures visibility	High
Structures artefacts	Medium-low
Position regarding impactful infrastructure	Direct incidence area
	Dam to a height of 170 +1
Impactful infrastructure	Submersion due the filling of dam
Impact evaluation	
Access	From Santa Luzia Station.



Layouts and Elevations

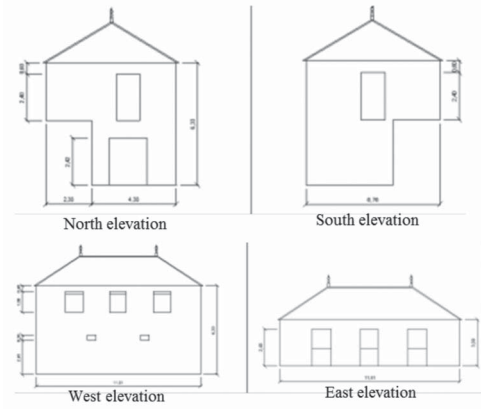


Figure 3. Dwelling houses: (a) house 6; (b) house 55. Credits: Authors.

2.3.3 Windows and doors openings

At the corners and wedges of the walls it was observed the presence of carved elements with larger stones, for strengthening these spaces. At the windows and door lintels, as well as, on the side of doors and windows, big stones are applied. This technique aimed at promoting enough resistance to bending stresses at lintels, even if the openings of the windows and doors have reduced size and are made only in places critically needed, see Figure 4.

As the glass was an expensive material, the windows and doors were entirely in wood, allowing only illuminating the space when open. In other situations the openings in the walls are reduced to small holes, whose function was to ventilate and illuminate the space (see Figure 4).

2.3.4 Roof

With regard to the roof, this is generally formed by a structure in wooden beams disposed longitudinally in the direction of the slope, supported on the load-bearing stone masonry walls, with a continuous wooden liner at the top, supported by

House with one floor and cellar with rectangular plan. Presents hipped roof, laid by a wooden continuous liner, supported by beams and two triangular wooden trusses. The ground floor has three entrances facing east and in the cellar there exist one entrance in the north facade. Masonry walls with granite blocks of irregular size and shape, with mortar coating (plaster) at the ground floor characterize the structural system. In the cellar, in each of the extremities of the east facade, the plaster has outlined in black ink and the pillars are type Doric. The edges of the lintels are represented in the same way.

these beams (wooden beams) and two triangular wooden trusses. It is under this structure that clay tiles are applied with or without bedding mortar (Figure 5). In some cases, simple timber trusses are also applied.

All the houses studied presented the roof as the first structural element that undertakes degradation. The impermeability of the roof is guaranteed by the way the tiles are overlapped and fitted in each other. In this way all rainwater is directed to the eaves, without returning down the tiles. Any anomalies in fitting of the elements, namely, broken tiles or displacements, result in a weak point for entrance of water. In situations where the protection of the tiles is not effective, widespread degradation occurs, leading to its downfall, which could be seen in the houses analysed. In general, the wood beams are the first elements that exhibit increasing deformations, because they have the ability to withstand the weight of the remaining coating. It was also observed that in the local of embedding wooden trusses in the bearing walls, holes of sufficient size were made, so that the wood does not get confined allowing the ventilation of the supporting zones. The moisture and biological agents are the main agents that contribute for the attack of the wood, leaving it hollow and with reduced resistance.

A fundamental element of the roof shown in Figure 5 is the eave, whose function is the routing of the water into a zone spaced from the walls. The roof shown in this figure is a hip roof, but the most common situation identified is a gable roof, which terminates in an eave sufficiently protruding from the outer walls. This technique proves to be effective as the coating below the eaves was found to be in relatively good state of preservation, which is a visible signal that the water does not focus directly on this site, nor runs down the wall.

Relation with the architecture of the villages of Codeçais and Amieiro (Alders).

The houses identified along the margins of the Tua River revealed the use of the local raw materials and very primitive construction techniques, ruled by simplicity, passive systems and low-tech technologies. Thus, an ascertained survey was conducted on the built heritage. Two villages near Foz Tua, belonging to the municipality of Alijó were selected: Codeçais and Amieiro. This selection related also to the possibility of using distinct case studies in these sites to carry out in-situ experimental tests aiming at characterizing the mechanical behaviour of traditional stone masonry walls. These villages present an important architectonic legacy from the identity and economic point of view. Thus, the conservation of these buildings should be of paramount importance for the residents and also for the society in general. In this

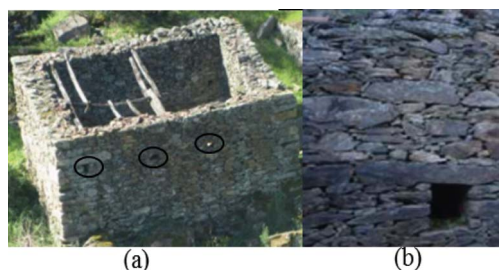


Figure 4. (a) Holes/openings: (a) house 14; (b) house 10. Credits: The authors.



Figure 5. Construction 38 (house) – roof with tile. Credits: Authors.

scope, recommendations of the “Charter about the constructive vernacular heritage”, should be considered by taking into account the principles and guidelines about research, importance of localization, adaptation and change of uses, importance of training professionals and communities, exchange of expertise and experiences between regional networks, among others (Fernandes *et al.*, 2012).

In relation of the material commonly identified in the village of Amieiro and Codeçais the stone (granite and schist) is of the same type of the construction identified along the railways line of the Tua river. The houses have carved stone masonry, with several sizes and mostly dry joints, have being identified some examples of carved masonry with mortar joint and plastered with lime, as seen Figure 6.

A distinct feature of the dwellings of Codeçais and Amieiro villages with respect of the constructions identified along the Tua River refers to dimension of the houses and to the masonry bonds used. The residential houses of Codeçais and Amieiro have a considerably higher area and ordinary masonry walls. It is common to find granitic masonry walls composed of large granite blocks and in few cases almost regular masonry. Besides, the masonry is more often coated by a lime mortar.

The extensive use of wood in dwelling houses is evident in the balconies and roofing. In fact, the balconies are a real example of application of the wood, and it is an architectonic feature present in almost all

of the houses in Amieiro village. The balconies are designed in cantilever, being supported in the stone walls and projected to the outside. The shoring is carried out through the wooden elements (beams), whose support base is the masonry wall. The roof is extended to the balconies in order to provide additional protection from the climacteric agents. These balconies are south oriented to take advantage of the solar gains. In Figure 7 it is also possible to observe the use of wooden walls in upper floors. In fact, along of the Tua River dense forests of chestnut trees, pines, cork oak, oaks and alders (characteristic tree of the Amieiro) exist, which promoted the use of this material in the houses of this region.

The structural system of the timber walls consists of a timber structure formed by a sequence of vertical boards aligned in the plane of the wall, and connected together on both sides by horizontal wooden slats. The connection between vertical and horizontal elements is materialized by metallic nails. The wooden structure is filled and coated on both sides by earthy material (simple earth or earthen bastard mortar and lime) (Pinto *et al.*, 2011). In Figure 7 the outer face of these walls were coated with lime mortar to provide additional protection to biological agents and water. These walls are very sensitive to water, reason by which this type of wall is not performed on ground floor. In addition, these walls are not thought for structural purposes and in this case only receive the loads of the roof. The number of floors in the village of Codeçais and Amieiro is commonly of three floors (ground floor and two upper floors). The ground floor was often used for placement of the cattle and the upper floors served as housing in order to take advantage of the heat generated by the animals.

8 FINAL REMARKS

The vernacular architecture of stone masonry reveals a high aesthetic, cultural and heritage value, as well as a potential for considerable durability, where its large thermal inertia is its strong sustainable feature. The multiple geographical and climatic asymmetries of the Portuguese territory led to a wide variety of expression of vernacular architecture. Its regional differentiation is expressed in the use of local materials and techniques, in climate adaptation and economic activity of the families. The mills are one of the best examples of vernacular architecture for harvesting renewable energy. The wood and the stone are natural materials locally available and have reduced embodied energy when compared to other construction materials. Thus, it can be stated that these constructive techniques are economic and sustainable.



Figure 6. Traditional dwelling house in Amieiro—Alijó. Credits: Authors.

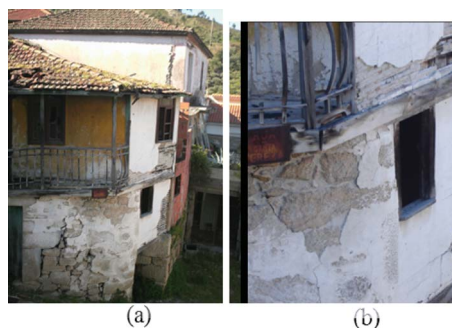


Figure 7. (a) Exterior wooden wall on the 1st and 2nd floor of the house, (b) detail of the wall (Amieiro-Alijó). Credits: Authors.

The vernacular heritage should be considered as a privileged factor of local development and a starting point for its valorisation and conservation. This can contribute to the stimulation of the local economies, through research, professional training in traditional techniques and conservation actions or adaptation of existent vernacular heritage.

The dissemination and success of these actions will promote the rebirth of small industries of traditional local materials, reducing energy requirements in the production and transportation.

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